DSS 14 Operating Noise Temperature During Helios 1 Near-Sun Tracking

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When spacecraft are tracked near the line-of-sight of the Sun, the ground antenna sidelobes "see" the solar noise. The solar noise increases the ground system operating noise temperature and degrades the downlink RF reception performance. At specific antenna azimuthal angles relative to the Sun, noise peaks and nulls occur periodically throughout a day's tracking pass due to the quadripod support leg-generated sidelobes. This article documents this effect while tracking Helios 1, illustrates the time of the peaks, and compares the predicted time of the noise temperature peaks with the measured data.

I. Introduction

The ground antenna sidelobes "see" solar noise when tracking a spacecraft near the Sun line-of-sight. The solar noise increases the ground system operating noise temperature and degrades the downlink sensitivity. This occurs when the Goldstone Mars Deep Space Station (DSS 14) 64-m antenna operates at 2.2 GHz and the Sun–Earth–probe (SEP) angles are less than about 5 deg. Periodic peaks and nulls occur in the operating noise temperature (T_{op}) during a day's track. This is shown in the idealized curves of Fig. 1 and results from the Sun passing through the sidelobe positions of the ground antenna pattern as distorted by the quadripod support legs (Refs. 1 and 2). The azimuthal angle ϕ is defined in Fig. 2 for the northern hemisphere. (Reverse N–S and E–W on the figure in the southern hemisphere; all other figures assume northern hemisphere.)

II. Prediction of T_{op} Peak and Null Times of Occurrence

Figures 3 and 4 show plots of the "Sun path" for DSS 14 & 63 and DSS 43, respectively, computed from the Sun and Helios 1 spacecraft difference declination and difference right ascension as obtained from station-supplied computer polarization predicts and The American Ephemeris and National Almanac. These data are listed in Table 1 for Helios 1 for the period April 8 to May 12, 1975. The solid straight lines represent the values of ϕ (60, 120, 240, 300 deg) for the sidelobe peaks previously discussed. The dashed straight lines, offset 12 deg from these peaks, are required to predict peak temperature duration times. Also shown is a typical sidelobe–Sun angle (SSA) representing the azimuthal difference angle between the sidelobe and the Sun applicable at meridian transit only:

$$\text{SSA} = \text{sidelobe angle} - \text{Sun path angle}$$

For this example (Fig. 3) on May 8, SSA $= -13$ deg for $\phi = 280$ deg. The graph is used to read off values for SSA over the time period April 8 to May 12, 1975 and listed in Table 2. SSA is always less than 60 deg.

Figure 5 shows a graph useful for predicting the approximate polarizer setting as a function of spacecraft right ascension and declination and antenna hour angle. The polarizer predicts at meridian transit are used with SSA to predict the time of peak T_{op} (Philco memo M-0875-110, 27 August 1975). This has been calculated and tabulated for Helios 1 in Table 3.

Figure 6 shows a plot of DSS 14 T_{op} measurements while tracking Helios 1 in the near-Sun region as a function of time of day. Also shown are the predicted times of maximum T_{op}.

Figure 7 shows a plot of the DSS 14 T_{op} measurements as a function of Sun–Earth–probe angle comparing peak and minimum values for Pioneer 6 data (near solar cycle maximum) and Helios 1 data (near solar cycle minimum).

References

1. Bathker, D. A., "Large Ground Antenna Performance with Solar Noise Jamming," *Proc. IEEE*, Vol. 54, p. 1949, Dec. 1966.
2. Stelzried, C. T., *A Faraday Rotation Measurement of a 13-cm Signal in the Solar Corona*, Technical Report 32-1401, p. 33, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1970.

Table 1. Sun/Helios 1 position angle differences for first superior conjunction

Day of year (1975)	Right ascension, deg	Declination, deg
98	4.475	1.872
102	3.270	1.332
108	1.933	0.749
112	1.311	0.488
116	0.870	0.310
120	0.611	0.201
124	0.454	0.147
128	0.445	0.134
132	0.547	0.150

Table 2. Sun/sidelobe angle (SSA) azimuthal position for Helios 1 (applicable at meridian transit only)

Day of year (1975)	DSS 14 and DSS 63		DSS 43	
	SSA (for peak of ϕ = 300°), deg	SSA (for peak of ϕ = 240°), deg	SSA (for peak of ϕ = 60°), deg	SSA (for peak of ϕ = 120°), deg
98	52.8	−7.2	−7.2	52.8
102	52.2	−7.8	−7.8	52.2
108	51.5	−8.5	−8.5	51.5
112	50.0	−10.0	−10.0	50.0
116	49.5	−10.5	−10.5	49.5
120	48.6	−11.4	−11.4	48.6
124	47.8	−12.2	−12.2	47.8
128	47.0	−13.0	−13.0	47.0
132	46.4	−13.6	−13.6	46.4

Table 3. Calculated peak T_{op} for Helios 1

SEP, deg	Day of year (1975)	Time, GMT								T_{op}, kelvins	
		ϕ = 300°				ϕ = 240°					
		Start	Peak	End	Duration, min	Start	Peak	End	Duration, min	Peaks (both)	Low
1.25	113	≈13:33	17:00	18:11	278	19:34	20:01	20:28	54	130	45
0.83	117	13:32	17:17	18:13	281	19:36	20:02	20:28	52	280	100
0.58	121	13:32	17:26	18:15	283	19:38	20:03	20:28	50	610	270
0.53	122	13:31	17:36	18:17	286	19:38	20:03	20:28	50	850	410
0.48	124	13:31	17:42	18:20	289	19:40	20:04	20:28	48	1200	630
0.47	125	13:30	17:45	18:23	293	19:40	20:04	20:28	48	1400	770
0.46	127	13:30	17:51	18:27	297	19:41	20:03	20:27	46	1800	850
0.48	129	13:29	18:02	18:30	301	19:42	20:03	20:26	44	1340	720
0.51	130	13:28	18:03	18:34	306	19:42	20:02	20:25	43	1050	520
0.61	133	16:38	18:04	18:39	121	19:43	20:01	20:25	42	540	250
0.66	134	17:25	18:10	18:41	116	19:44	20:01	20:24	40	460	190

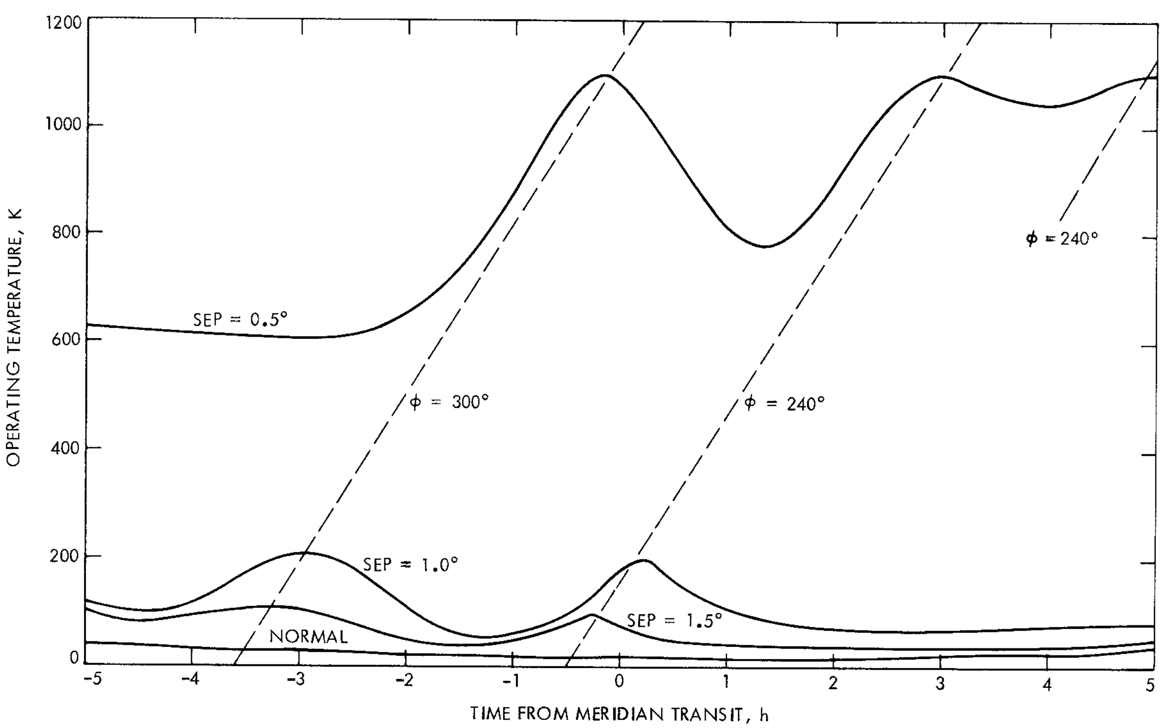

Fig. 1. Idealized curves showing system operating noise temperatures when tracking near the Sun

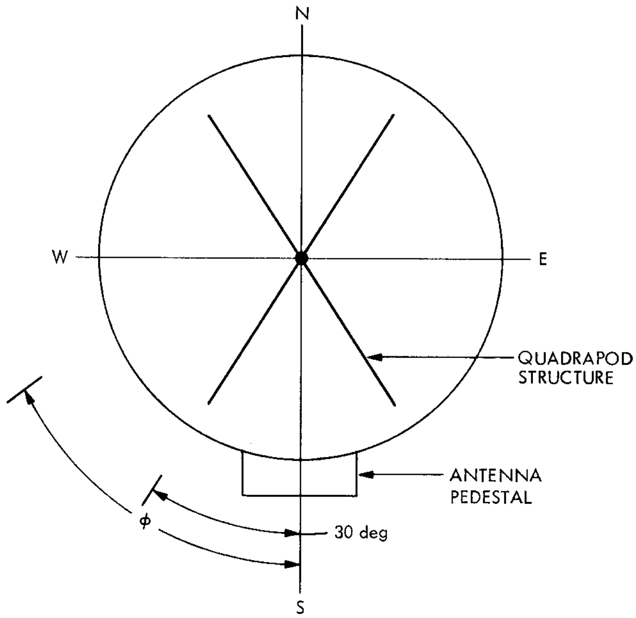

Fig. 2. Reflector coordinate system (looking toward dish) defining azimuthal angle ϕ

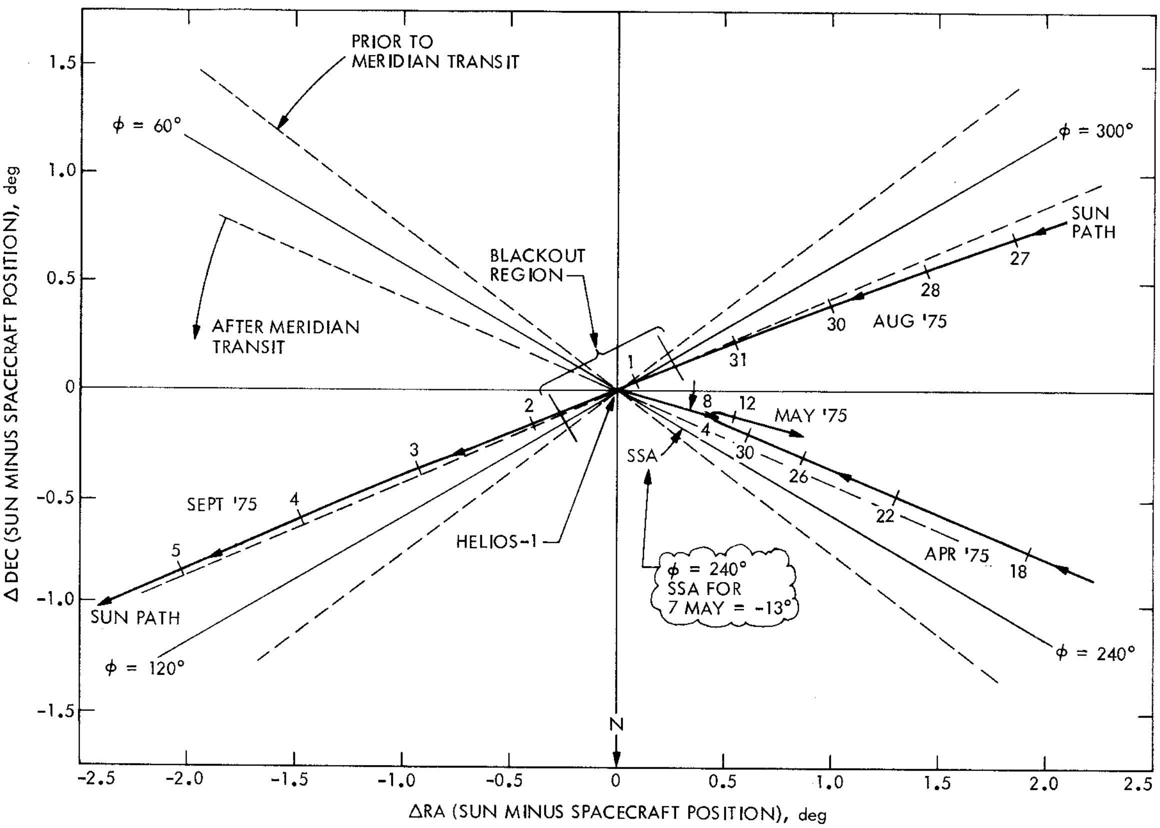

Fig. 3. Plot of position relative to Helios 1 for DSS 14/63

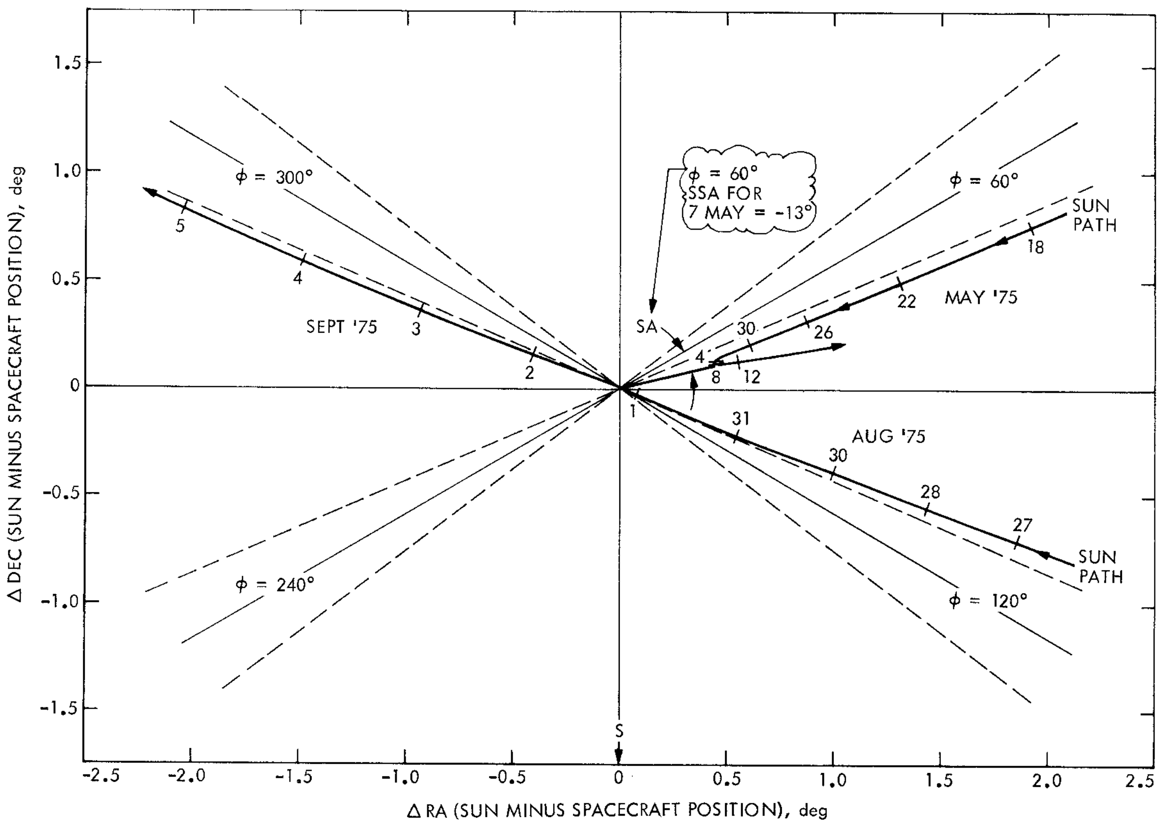

Fig. 4. Plot of position relative to Helios 1 for DSS 43

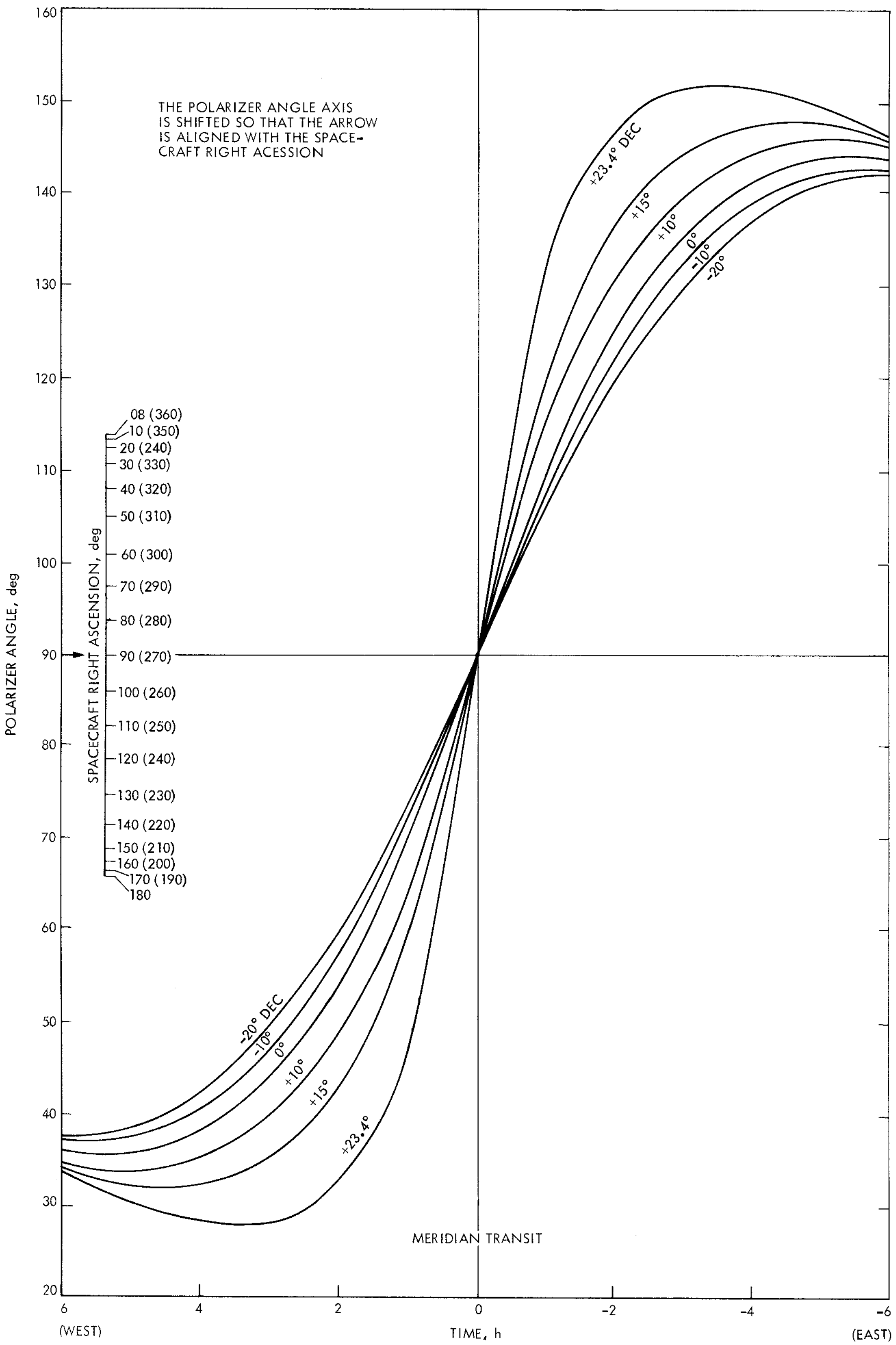

Fig. 5. Polarization angle prediction graph for DSS 14/63

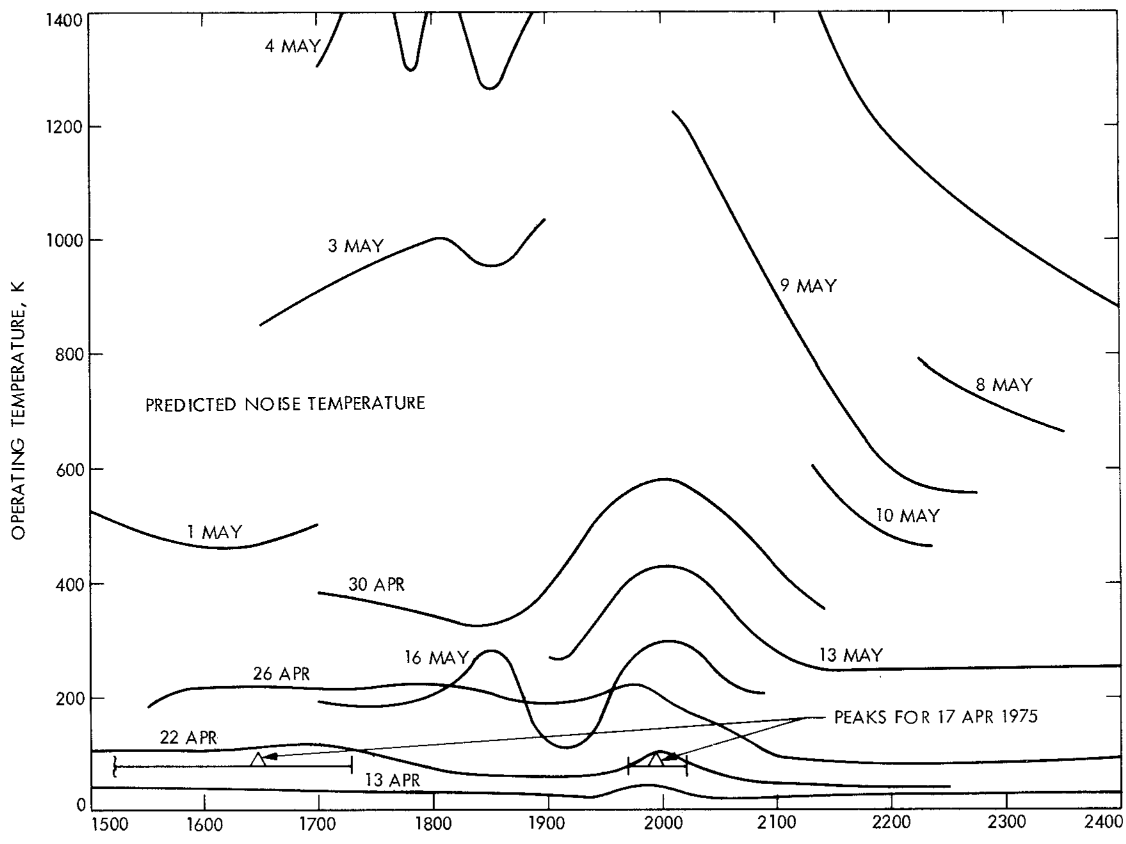

Fig. 6. System operating noise temperature during Helios 1 track in the near-solar region as a function of time of track

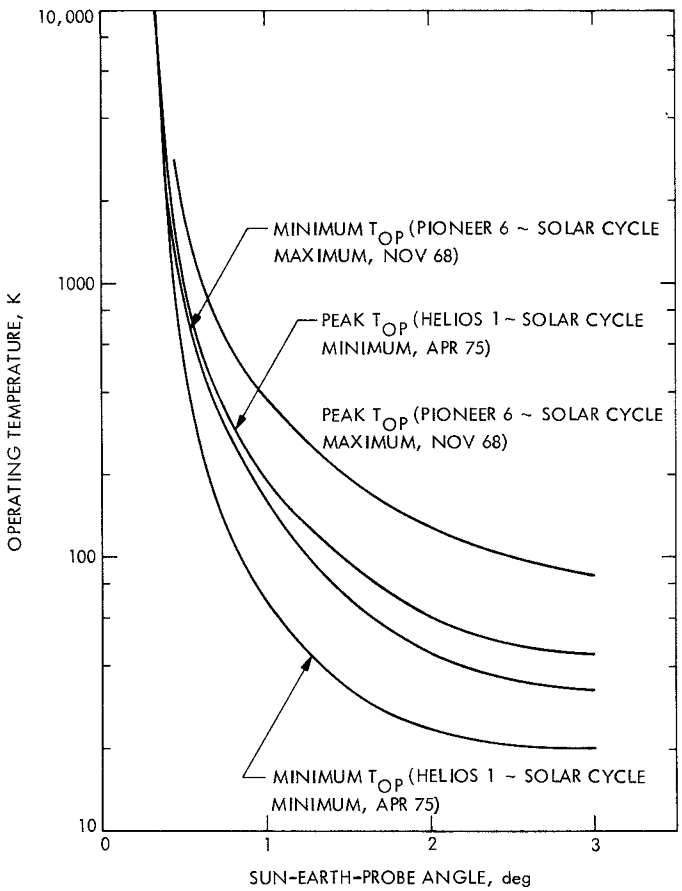

Fig. 7. System operating noise temperature during Helios 1 track in the near-solar region as a function of Sun-Earth-probe angle